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**UNIVERSITY OF TORONTO
STUDIES**

**PAPERS FROM THE CHEMICAL
LABORATORIES**

**No. 82: THE HYDRATES AND ACID SALTS OF FERROUS
SULPHATE, BY FRANK B. KENRICK**

(REPRINTED FROM THE JOURNAL OF PHYSICAL CHEMISTRY, VOL. XII)

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THE HYDRATES AND ACID SALTS OF FERROUS SULPHATE

FRANK B. KENRICK

A large number of ferrous sulphates have been described by various authors. The following are mentioned, with references, by Dammer:¹ $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 4\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 3\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 2\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot \text{H}_2\text{O}$, FeSO_4 , $\text{FeSO}_4 \cdot \text{H}_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 5\text{H}_2\text{SO}_4 \cdot 5\text{H}_2\text{O}$ and FeS_2O_7 . Many of these were prepared in contact with sulphuric acid of considerable concentration, and as this is extremely difficult to separate from the solid substance and as the analyses were often made after drying either by a current of air (Jeremin, $\text{FeSO}_4 \cdot \text{H}_2\text{O}$ and $\text{FeSO}_4 \cdot 5\text{H}_2\text{SO}_4 \cdot 5\text{H}_2\text{O}$)² or over concentrated sulphuric acid (Bolas, "Ferrous anhydro-sulphate," FeS_2O_7)³, it is quite probable that the formulae given by these authors do not in all cases represent the true composition of the solid phases. The following experiments were carried out with the hope of fixing more definitely the composition of some of the ferrous sulphates stable in contact with solutions of sulphuric acid.

Method.—Powdered recrystallized ferrous sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) was mixed with sulphuric acid of various concentrations in glass stoppered bottles and shaken at room temperature in a mechanical shaker until the composition of the liquid became constant. Glass marbles were added to each bottle to aid the stirring. To prevent oxidation, which in the longer experiments was found to be quite appreciable, the free spaces in the bottles were filled with nitrogen by blowing in a rapid stream of this gas before inserting the vaselined stoppers. The nitrogen was prepared from ammonium chloride, sodium nitrite and potassium bichro-

¹ Handbuch anorg. Chemie, III, 329, 330, 337 (1893).

² Ber. chem. Ges. Berlin, 21, R, 590 (1888).

³ Jour. Chem. Soc., 27, 212 (1874).

mate, washed by ferrous sulphate and soda lye, and kept in a gas-holder over weak lye.

After equilibrium was established and the bottles had stood upright for a day or so, the solid, which slowly settled to the bottom as a paste, was sucked up into a centrifuge tube. This was a cylindrical glass tube, temporarily closed at both ends by rubber stoppers carrying tubes of small bore. Immediately the tube was full, the temporary stoppers were replaced by rubber plugs faced with platinum discs. After centrifuging for 20 minutes, the plug at the upper end was removed, the liquid poured quickly into a weighing bottle and the plug immediately replaced. The other plug was next taken out, and the first plug pushed through the cylinder thus forcing out the cake of paste which was caught in the weighing bottle. In this way the contents of the centrifuge were transferred to the weighing bottles without more than a couple of seconds' exposure to the moisture of the atmosphere.

Determination of Composition of the Solid Phase.—Two methods were adopted for ascertaining the composition of the solid phases. Each alone is insufficiently accurate to settle definitely the composition, but together they afford a solution of the problem.

The first method consisted in analyzing liquid and wet solid over a range of varying composition of the liquid phase and obtaining the composition of the dry solid graphically from pairs of such analyses. Unfortunately, the difficulty of separating the liquid from the solid and the small range of concentration of liquid possible in some of the cases investigated combine to magnify enormously the effect of experimental error on the composition of the solid. For example, in the case of the compound $2\text{FeO}_3\text{SO}_3 \cdot 2\text{H}_2\text{O}$,¹ taking the most favorable possible pair of analyses, an error of 0.1 percent in the determination of the SO_3 in one of the

¹ With this substance, the paste always contained from 65–75 percent of liquid phase after centrifuging. Even after leaving it on a porous plate in an exsiccator over the mother-liquor as much as 60 percent remained.

pastes, would cause an error of about 6 percent in the ratio of H_2O to SO_3 in the dry solid. By the ordinary gravimetric method of determining SO_3 in the presence of iron it was not found possible to obtain results sufficiently accurate for the purpose, but a method based on specific gravity determinations, described below, proved quite satisfactory. (Duplicates agreed consistently to 0.1 percent.)

The second method adopted, consisted in adding to the mixture a "tell-tale" substance which dissolved in the liquid without entering into the composition of the solid phase, and determining the quantity of the liquid in the wet solid from the amount of the tell-tale found. For this purpose, ammonium sulphate was used. It was hoped that by using different tell-tales in duplicate experiments their non-participation in the solid could be proved from the identity of the composition calculated for the solid phase, but a satisfactory second tell-tale substance was not found. However, by adding the ammonium sulphate in small quantities after equilibrium was established the chance of its forming solid solutions was minimized. The far greater analytical errors of this method are partly compensated for by their much smaller effect on the result. For example, taking, as before, the case of $2FeO_3SO_3 \cdot 2H_2O$, an error of 0.1 percent in the SO_3 in the wet solid would cause an error of only about 1.5 percent in the ratio of H_2O to SO_3 in the dry solid. On the ratio of FeO to SO_3 , both of which were determined directly, the effect of the error is much smaller, and the method serves to give this ratio with a fair degree of accuracy.

Composition by Specific Gravity Method.—Stock solutions of sulphuric acid and of ferrous sulphate were prepared and carefully analyzed—the former gravimetrically and the latter by permanganate. With these, a number of solutions were made up, all containing 0.000499 formula weights FeO per gram but varying quantities of SO_3 . The specific gravity of these was found at 25.0° in a 20 cc pyknometer. The results are expressed by the interpolation formula:

$$y = 41.07 + 1.2643x - 0.001865x^2 + 0.000004257x^3,$$

where y = grams of SO_2 per kilo of solution and x = (sp. gr. $\times 1000$) — 1080. The specific gravity is compared with water at 25° and uncorrected. In making the analyses of the wet solids, a weighed quantity of water, sufficient to effect solution, was added to the substance and the FeO determined in a portion of this liquid by $n/10$ permanganate. Enough water was then added to reduce the concentration of the iron to that to which the interpolation formula applied, and finally the specific gravity of the solution taken. The SO_2 in the wet solid was calculated from the formula, the FeO from the permanganate reading, and the water by difference.

The liquid phases, except those in equilibrium with tetra- and heptahydrates, contained only traces of iron. In these it was found that the SO_2 could be determined quite accurately with $n/5$ potassium hydroxide. The small quantity of iron was precipitated and oxidized to ferric hydroxide; directly, excess of alkali was added and had no effect on the end-point. The results of the analyses are given in the following table.

TABLE I¹

Number	Receipt	Comp. of liquid. To 1 SO_2	Comp. of wet solid. To total of 1 formula weight	Solid phase
1	Residue ² 370 cc acid ³ 120 cc fuming acid	1.122 H_2O 0.0002 FeO	0.0494 FeO 0.4835 SO_2 0.4671 H_2O	$\text{FeO}_4\text{SO}_{3.3}\text{H}_2\text{O}$
2	Residue 450 cc acid	1.226 H_2O 0.0004 FeO	0.0428 FeO 0.4695 SO_2 0.4877 H_2O	$\text{FeO}_4\text{SO}_{3.3}\text{H}_2\text{O}$

¹ In Experiments 1-4 another interpolation formula was used corresponding to a smaller concentration of FeO. In Exps. 20-22 the SO_2 was determined directly as barium sulphate.

² By "residue" is meant the wet solid made by shaking 40 grams ferrous sulphate heptahydrate with 470 cc concentrated sulphuric acid and pouring off the liquid.

³ By "acid" is meant chemically pure sulphuric acid, specific gravity 1.84.

TABLE I—(Continued)

Number	Receipt	Comp. of liquid. To 1 SO ₃	Comp. of wet solid. To total of 1 formula weight	Solid phase
3	20 gram salt ¹ 460 cc acid	1.275 H ₂ O 0.0005 FeO	0.0497 FeO 0.4632 SO ₃ 0.4871 H ₂ O	FeO ₄ SO ₃ 3H ₂ O
4	Identical with No. 2 + 15 cc water	1.342 H ₂ O ? FeO	0.0434 FeO 0.4391 SO ₃ 0.5175 H ₂ O	FeO ₂ SO ₃ H ₂ O
5	40 gram salt 400 cc acid	1.382 H ₂ O ? FeO	0.0737 FeO 0.4676 SO ₃ 0.4587 H ₂ O	FeO ₄ SO ₃ 3H ₂ O probably in un- stable equilib.
6	20 gram salt 200 cc acid	1.407 H ₂ O 0.0008 FeO	0.1120 FeO 0.4550 SO ₃ 0.4330 H ₂ O	FeO ₂ SO ₃ H ₂ O
7	30 gram salt 200 cc acid	1.456 H ₂ O 0.0009 FeO	0.1153 FeO 0.4482 SO ₃ 0.4365 H ₂ O	FeO ₂ SO ₃ H ₂ O
8	45 gram salt 200 cc acid	1.595 H ₂ O 0.0013 FeO	0.1191 FeO 0.4372 SO ₃ 0.4437 H ₂ O	FeO ₂ SO ₃ H ₂ O
9	55 gram salt 200 cc acid	1.637 H ₂ O 0.0014 FeO	0.0690 FeO 0.3902 SO ₃ 0.5408 H ₂ O	2FeO ₃ SO ₃ 2H ₂ O
10	60 grams salt 200 cc acid	1.697 H ₂ O 0.0014 FeO	0.0634 FeO 0.3866 SO ₃ 0.5500 H ₂ O	2FeO ₃ SO ₃ 2H ₂ O
11	85 grams salt 200 cc acid	1.822 H ₂ O 0.0011 FeO	0.0632 FeO 0.3678 SO ₃ 0.5690 H ₂ O	2FeO ₃ SO ₃ 2H ₂ O
12	100 grams salt 200 cc acid	1.951 H ₂ O 0.0010 FeO	0.0636 FeO 0.3591 SO ₃ 0.5773 H ₂ O	2FeO ₃ SO ₃ 2H ₂ O
14	90 grams salt 150 cc acid	2.209 H ₂ O 0.0011 FeO	0.0853 FeO 0.3442 SO ₃ 0.5705 H ₂ O	2FeO ₃ SO ₃ 2H ₂ O

¹ By "salt" is meant recrystallized ferrous sulphate heptahydrate.

TABLE I—(Continued)

Number	Receipt	Comp. of liquid. To 1 SO ₃	Comp. of wet solid. To total of 1 formula weight	Solid phase
13	112.5 grams salt 150 cc acid	2.186 H ₂ O 0.0011 FeO	0.1770 FeO 0.3462 SO ₃ 0.4768 H ₂ O	Two phases: 2FeO ₃ SO ₃ ·2H ₂ O FeOSO ₃ ·H ₂ O
15	75 grams salt 150 cc acid 26 cc water	2.385 H ₂ O 0.0006 FeO	0.1496 FeO 0.3134 SO ₃ 0.5370 H ₂ O	FeOSO ₃ ·H ₂ O
16	75 grams salt 150 cc acid 41 cc water	2.685 H ₂ O 0.0004 FeO	0.1718 FeO 0.3016 SO ₃ 0.5266 H ₂ O	FeOSO ₃ ·H ₂ O
17	60 grams salt 120 cc acid 56 cc water	3.200 H ₂ O 0.0005 FeO	0.1366 FeO 0.2750 SO ₃ 0.5884 H ₂ O	FeOSO ₃ ·H ₂ O
18	60 grams salt 120 cc acid 80 cc water	3.921 H ₂ O 0.0006 FeO	0.1285 FeO 0.2531 SO ₃ 0.6184 H ₂ O	FeOSO ₃ ·H ₂ O
19	80 grams salt 100 cc acid 100 cc water	5.107 H ₂ O 0.0021 FeO	0.1119 FeO 0.2210 SO ₃ 0.6671 H ₂ O	FeOSO ₃ ·H ₂ O
20	28 grams salt 7 cc acid 15 cc water	7.93 H ₂ O 0.106 FeO	0.197 FeO 0.236 SO ₃ 0.567 H ₂ O blue crystals dried 1 FeO 1.001 SO ₃ 6.974 H ₂ O	Two phases: FeOSO ₃ ·H ₂ O FeOSO ₃ ·7H ₂ O
21	28 grams salt 7 cc acid 15 cc water	8.97 H ₂ O 0.142 FeO	Dried crystals 1 FeO 1.004 SO ₃ 4.15 H ₂ O	FeOSO ₃ ·4H ₂ O
22	28 grams salt 3 cc acid 20 cc water	15.0 H ₂ O 0.287 FeO	Dried crystals 1 FeO 0.999 SO ₃ 7.11 H ₂ O	FeOSO ₃ ·7H ₂ O

Explanation of Table I.—The numbers in the first column correspond with the numbers in the triangular diagram (See Figure) in which each corner represents one formula weight of the substance marked.

The second column contains the receipts by which the mixtures were made up (See foot-notes).

In the third column, the composition of the liquid phase is given in formula weights of H_2O and FeO to one SO_3 .

Column four shows the composition of wet solid in formula weights of each constituent to a total of one formula weight (except in the case of the dried crystals, Exps. 20–22).

The last column shows the most probable formula of the solid phase.

Discussion of Results.—The lines for Exps. 1, 2, 3 and 5 meet very nearly in the point corresponding to the compound $FeO_4SO_3 \cdot 3H_2O$ (See Figure), and this formula is definitely confirmed by Exp. 23 of the next section (See Table II).

In Exps. 4, 6, 7 and 8, the lines converge in the direction of the point corresponding to $FeO_2SO_3 \cdot H_2O$, but the angle made by the lines is so small that the compounds $4FeO_6SO_3 \cdot H_2O$ or even the anhydrous $3FeO_4SO_3$ (marked with crosses on the diagram) might also be said to represent the point of convergence. Exps. 24, 25 and 26 of the next section, fix the ratio of FeO to SO_3 as FeO_2SO_3 ; hence the formula $FeO_2SO_3 \cdot H_2O$ represents the composition of the solid. The result of Exp. 4 is doubtful. The solid phase in the bottle was undoubtedly identical with that in Exps. 1, 2 and 3, both in texture of the paste and in microscopic appearance. The position of the points can only be accounted for by the assumption that the solid was in unstable equilibrium and changed in the centrifuge to the $FeO_2SO_3 \cdot H_2O$.

In Exps. 9, 10, 11, 12 and 14 the meeting point of the lines is not well-marked, probably owing to the large portion of liquid in the pastes analyzed, but the irregularity of the directions does not warrant the assumption of a solid solution. The points corresponding to the formulae $FeOSO_3$, $3FeO_4SO_3 \cdot 2H_2O$, $2FeO_3SO_3 \cdot 2H_2O$, $3FeO_5SO_3 \cdot 4H_2O$, $FeO_2SO_3 \cdot 2H_2O$,

etc., in which the ratio of FeO to SO_3 increases from 1:1 to 1:2, all lie in the general direction of the lines. Exps. 27 to 30, below, point to the ratio $2\text{FeO}:3\text{SO}_3$ (possibly $3\text{FeO}:5\text{SO}_3$) as the most probable, corresponding with the formula $2\text{FeO} \cdot 3\text{SO}_3 \cdot 2\text{H}_2\text{O}$ (possibly $3\text{FeO} \cdot 5\text{SO}_3 \cdot 4\text{H}_2\text{O}$).

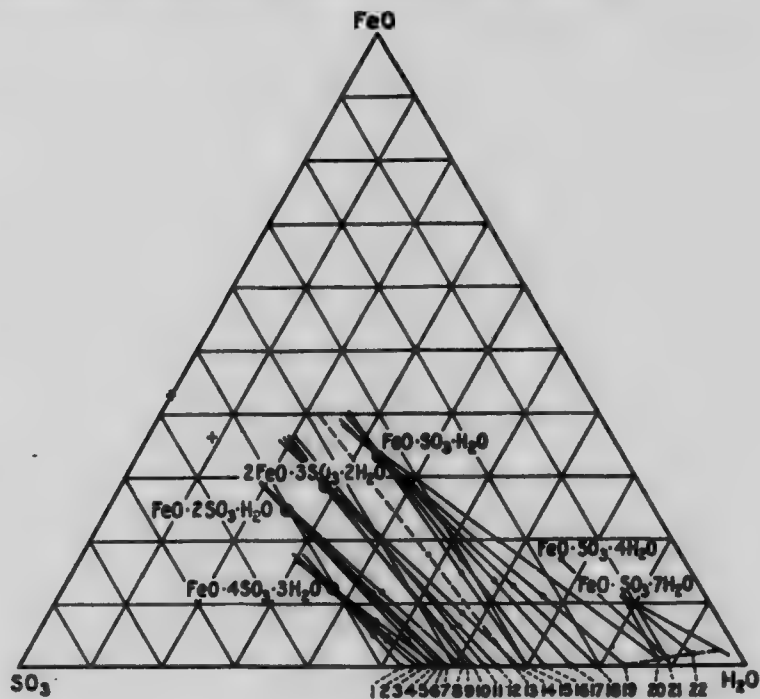


Fig. 1

In Exp. 13, two solid phases were distinctly seen under the microscope.

Exps. 15 to 20 leave little doubt that the corresponding solid phase in these cases is $\text{FeOSO}_3\text{H}_2\text{O}$. This formula is confirmed by Exp. 31, below.

In Exp. 20, the solid consisted of two phases, one, blue and the other white. The blue crystals were picked out, dried with filter paper, and found to be heptahydrate (in unstable equilibrium). The white paste was analyzed and gave the point in the diagram on the line drawn towards

$\text{FeOSO}_3\text{H}_2\text{O}$. On another occasion, the same mixture gave the result shown in Exp. 21, namely, the tetrahydrate. A detailed investigation of the salts in equilibrium with these weaker acids was not made.

Composition by Ammonium Sulphate Method.—In these experiments, FeO , SO_3 , $(\text{NH}_4)_2\text{O}$ and H_2O were determined in both liquid and wet solid. The iron was determined by permanganate, the sulphuric acid as barium sulphate after removing the iron by precipitating twice with ammonia, and the small amount of ammonium by distilling with excess of lye and titrating the distillate. The water was determined by difference. The ratio of ammonium in liquid and wet solid, which unfortunately could not be determined very accurately, gave the amount of liquid in the wet solid. The results calculated for the dry solids are given in the following table. The values for the water, on which the effect of experimental error is greatest, are too inaccurate to be of much use, but the ratio of FeO to SO_3 is sufficiently accurate to enable one to decide between the various possible formulae given by the direction of the lines in the former method.

Explanation of Table.—The second column gives the receipts by which the mixtures were made up. For the meaning of the words Residue, Acid and Salt see foot-note to Table I. Under the heading "Ammonium Ratio" is given the ratio of $(\text{NH}_4)_2\text{O}$ in the wet solid to that in the solution, *per gram*.

The results have been discussed above in connection with the experiments in Table I.

Description of the solid phases.—The substance $\text{FeOSO}_3\text{H}_2\text{O}$ consists of very minute uniformly sized granular crystals about 0.001 mm in diameter. It is stable in contact with solutions of compositions from $\text{SO}_3.2.186\text{H}_2\text{O}$ to $\text{SO}_3.7.93\text{H}_2\text{O}$, at which point (in Exp. 20) the heptahydrate was formed. It is identical with the compound described by Jeremin¹ and may correspond with v. Bonsdorf's $\text{FeSO}_4\text{H}_2\text{SO}_4.6\text{H}_2\text{O}$, (A mixture of $\text{FeOSO}_3\text{H}_2\text{O}$ with 52.5 percent of solution $\text{SO}_3.6\text{H}_2\text{O}$ has this composition.)

¹ Ber. chem. Ges. Berlin, 21, R, 590 (1888).

TABLE II

Number	Receipt	Comp. of liquid. Formula weights to 1 SO ₃	Comp. of wet solid. Formula weights per gram	Ammonium ratio	Comp. of dry solid
23	Residue 400 cc acid 20 g Am. sulph.	1.23 H ₂ O 0.0004 FeO 0.0222 (NH ₄) ₂ O	0.001051 FeO 0.00940 SO ₃ 0.00921 H ₂ O 0.000115 (NH ₄) ₂ O	0.537	1 FeO 4.000 SO ₃ 2.7 H ₂ O
24	20 g Salt 200 cc Acid 20 g Am. sulph.	1.28 H ₂ O 0.0005 FeO 0.0414 (NH ₄) ₂ O	0.001532 FeO 0.00892 SO ₃ 0.00903 H ₂ O 0.000244 (NH ₄) ₂ O	0.621	1 FeO 1.99 SO ₃ 0.964 H ₂ O
25	20 g Salt 200 cc Acid 10 g Am. sul _{ph} .	1.304 H ₂ O 0.0005 FeO 0.0210 (NH ₄) ₂ O	0.001665 FeO 0.00897 SO ₃ 0.00865 H ₂ O 0.000119 (NH ₄) ₂ O	0.592	1 FeO 1.997 SO ₃ 0.77 H ₂ O
26	20 g Salt 200 cc Acid 10 g Am. sulph.	1.345 H ₂ O 0.0005 FeO 0.0213 (NH ₄) ₂ O	0.002433 FeO 0.00849 SO ₃ 0.00783 H ₂ O 0.0000788 (NH ₄) ₂ O	0.390	1 FeO 1.97 SO ₃ 1.18 H ₂ O
27	30 g Salt 50 cc Acid 3 g Am. sulph.	1.98 H ₂ O 0.001 FeO 0.0245 (NH ₄) ₂ O	0.001036 FeO 0.00824 SO ₃ 0.0142 H ₂ O 0.000169 (NH ₄) ₂ O	0.737	2 FeO 3.25 SO ₃ 0.6 H ₂ O

TABLE II—(Continued)

Number	Receipt	Comp. of liquid. Formula weights to 1 SO ₃	Comp. of wet solid. Formula weights per gram	Ammonium ratio	Comp. of dry solid
28	35 g Salt 120 cc Acid 4 g Am. sulph.	1.66 H ₂ O 0.001 FeO 0.0145 (NH ₄) ₂ O	0.001655 FeO 0.00826 SO ₃ 0.0116 H ₂ O 0.000083 (NH ₄) ₂ O	0.633	2 FeO 3.04 SO ₃ 2.54 H ₂ O
29	55 g Salt 200 cc Acid 10 g Am. sulph.	1.62 H ₂ O 0.001 FeO 0.0220 (NH ₄) ₂ O	0.00213 FeO 0.00820 SO ₃ 0.0102 H ₂ O 0.000098 (NH ₄) ₂ O	0.695	2 FeO 2.94 SO ₃ 2.7 H ₂ O
30	30 g Salt 90 cc Acid 3 g Am. sulph.	1.69 H ₂ O 0.001 FeO 0.0144 (NH ₄) ₂ O	0.001196 FeO 0.00846 SO ₃ 0.0128 H ₂ O 0.0000959 (NH ₄) ₂ O	0.742	2 FeO 3.04 SO ₃ 2.63 H ₂ O
31	40 g Salt 50 cc Acid 50 cc Water 10 g Am. sulph.	4.74 H ₂ O 0.002 FeO 0.01121 (NH ₄) ₂ O	0.00322 FeO 0.00589 SO ₃ 0.0156 H ₂ O 0.000298 (NH ₄) ₂ O	0.466	1 FeO 0.987 SO ₃ 0.84 H ₂ O

The substance whose composition is probably $2\text{FeO}_3\text{SO}_3 \cdot 2\text{H}_2\text{O}$ consists apparently of fragments of small, extremely thin hexagons from 0.005 to 0.01 mm in diameter. Wet with the liquid phase, they form a very sticky paste. This paste was pure white in most cases, but in some of the earlier experiments where precautions were not taken to exclude the air, it had a distinct greenish tinge, possibly due to traces of ferric iron. It exists in contact with solutions $\text{SO}_3 \cdot 1.637\text{H}_2\text{O}$ (about) to $\text{SO}_3 \cdot 2.186\text{H}_2\text{O}$. It is probably the substance described by Jeremin¹ as "greenish shining crystals...very unstable," to which he assigns the formula $\text{FeSO}_4 \cdot 5\text{H}_2\text{SO}_4 \cdot 5\text{H}_2\text{O}$. This may well be so, since a mixture containing the compound with 71.3 percent of liquid phase (of composition $\text{SO}_3 \cdot 2\text{H}_2\text{O}$) has the composition of Jeremin's substance, and it is "unstable" in the sense that a very slight absorption of water from the atmosphere would cause it to change to the granular $\text{FeOSO}_3 \cdot \text{H}_2\text{O}$.

The compound $\text{FeO}_2\text{SO}_3 \cdot \text{H}_2\text{O}$ exists with solutions $\text{SO}_3 \cdot 1.342\text{H}_2\text{O}$ to (about) $\text{SO}_3 \cdot 1.595\text{H}_2\text{O}$. It consists of irregular groups of fine crystals of about 0.005 mm diameter, and is probably the "ferrous anhydrosulphate" of Bolas (FeS_2O_6) which he "dried" over concentrated sulphuric acid.

The compound $\text{FeO}_4\text{SO}_3 \cdot 3\text{H}_2\text{O}$ is stable with solutions ranging from the strongest one investigated, $\text{SO}_3 \cdot 1.122\text{H}_2\text{O}$, to (about) $\text{SO}_3 \cdot 1.342\text{H}_2\text{O}$. The crystals are fine needles, some of the largest being about 0.2 mm long. They dissolve rapidly in water, precipitating the $\text{FeOSO}_3 \cdot \text{H}_2\text{O}$.

The solubility of all the compounds in the liquid phases (*i. e.*, the amount of FeO found in the liquids) is, except in the cases of the tetra and heptahydrates, very small. There is a maximum amount of iron at the point corresponding to Exp. 9, and a minimum point near Exp. 17.

Summary.—The compositions of a number of ferrous sulphates and their range of existence with sulphuric acid solutions at ordinary temperatures have been determined.

¹ Loc. cit.

The composition of the solid phase was obtained by a combination of two methods of indirect analysis, each of which alone was insufficiently accurate for the purpose. In the first method, the analyses of liquids and corresponding wet solids gave the values of a and b in a number of equations to straight lines

$$y = ax + b, y = a'x + b', \text{ etc.,}$$

in which y = amount of FeO and x = amount of H₂O to 1SO₃, and the points on which correspond to possible compositions of the solid phase. In some cases the values of x and y representing the composition of the actual solid, could be determined from the cutting point of these lines; in others the smallness of the angles made this impracticable. In the second method, each analysis of liquid and corresponding wet solid gave the value of y fairly accurately, although the value found for x was too inaccurate to be of any use. By combining the two methods and substituting the value of y given by the second method in any of the equations obtained by the first the value of x could be determined.

*University of Toronto,
September, 1908.*